A comparison of the water quality between the mangrove areas Mulyorejo and Wonorejo

Luc Kauh^{1,3}, Kayleigh Lambregts^{1,3,*}, and Suntoyo²

¹Exchange student, Ocean Engineering Department, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia (60111)

²Associate Professor, Ocean Engineering Department, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia (60111)

³Student, Delta Academy, HZ University of Applied Sciences, Edisonweg 4, 4382 NW Vlissingen, The Netherlands

Abstract. The East Coast of Surabaya consists of large mangrove and fish pond areas. These areas are crucial for the ecosystem and for providing food and shelter for the local community. If the water quality decreases the mangroves will not be able to provide these functions. The water quality of these areas can be measured in two ways: by looking at the physico-chemical parameters or by looking at the biological parameters. Both offer a very good view of what state the area is in. The purpose of this study is to find out what the differences are between the Mulyorejo and the Wonorejo areas to see what differences there are within the East Coast of Surabaya and what could be the main cause of these differences. The data shows that the physico-chemical data does not comply with the limitation factors. The main problem are the nutrients which will have to be lowered to preserve the ecosystem. In terms of the biological state of the mangrove, there are few problems found. It is, however, unclear why the tree density in one of the Wonorejo areas is declining and it should be determined what the reason for this is.

Keywords: Mangrove, Fish ponds, Wonorejo, Mulyorejo, Physico-Chemical, Biological

1 Introduction

Mangroves are an important part of the coast line of Surabaya. They provide an ecosystem that protects the people and offer a source of food for both humans and aquatic species. The East Coast of Surabaya contains a large mangrove area. This mangrove area is divided in multiple parts which are all influenced by different rivers. The area is part of a development plan in which this area is meant as a place where the main functions are to protect and rehabilitate the marine environment, develop nature tourism as well as fishing and fishery cultivation areas.

The research is focused on two areas. The first area is the Mulyorejo area, which has a small river flowing through it and which is mainly influenced by domestic waste from

* Corresponding author: kayleighlambregts@hotmail.com

the city of Surabaya. The second area is the Wonorejo area, this area has a large river flowing through it, the Brantas river. This river flows through most of East-Java and brings in a lot of pollutants from its catchment area which makes it unclear where the main pollution is coming from even though there is extensive research being done in this area. Both areas are also greatly influenced by illegal logging for the creation of fish ponds and residential areas.

In this paper we aim to identify, analyze and compare these mangrove areas and fish ponds to determine what influences the urban runoff and domestic waste from the city of Surabaya bring into the system, and to see what influence the fish ponds and mangroves have on the water quality in these areas.

2 Theoretical background

2.1 Mangroves and fish ponds

Mangrove forests have adapted to the low oxygen and high salinity of the coastal zones. They limit their salt intake and their water loss. Next to that, they also stabilize the coastline, reduce erosion from storms, currents, waves and tides. Their root system allows them to live in this area. These roots also make an attractive living environment for many aquatic species as a breeding and feeding, and shelter area [1].

This also makes the area surrounding the mangroves interesting for fish ponds, these fish ponds need to receive an effluent or sludge. The fish can then feed on algae and other organisms but can also filter nutrient rich water from the mangroves. Fish that live in aerobic ponds can effectively reduce algae and help control mosquito populations. The fish do not improve the water quality a lot but due to their economic value can offset the cost of operating a treatment facility [2].

2.2 Coastal zone

The Indonesian coastal zone has a high potential to become the most important coastline in the world in terms of economic activity. The coastal zone also holds one of the richest ecosystems in the world, characterized by extensive mangroves, coral reefs and seagrass beds. These ecosystems play an important role in determining system response to environmental changes [3]. The mangroves represent the main ecosystem in marine and brackish coastal zones and contain large amounts of resources which support the major fisheries and mariculture activities [4].

2.3 Water quality

Water quality is defined in terms of the chemical, physical and biological contents of water [5]. The definition of water quality assessment has reached a level of complexity which requires simultaneous consideration of multiple aspects. This calls for a multi-dimensional approach to an inevitable necessity to assess the water quality. To measure the water quality, theoretically speaking, there are an infinite amount of ways in each kind of water body, every different pollutant, water use and combinations of these

depending on the objective. In practice, however, the amount of different measuring methods is limited due to influences from the environment, equipment, et cetera and are defined in different types (e.g., trend monitoring, basic survey, etc.) [6].

2.3.1 Physico-chemical

The physico-chemical parameters have a great influence on the aquatic system. Some of the most influential parameters being temperature, rainfall, pH, salinity, and dissolved oxygen. These factors have a limiting factor or the survival of aquatic organisms, such as flora and fauna. They can be altered by a variety of factors such as municipal effluents and industrial discharges [5].

2.3.2 Biological

Exposure of a biological community acts as an integrator of present and past environmental effects, this attribute makes them useful as indicators for the measurement of system changes. The response of these communities is well predictable and based on the indicator concept. This concept is well founded as observations that organisms reflect their environment are found in writing dating from as early as Aristotle [7].

3 Materials and method

This methodology is based on the methodology used by the Environmental Agency of Surabaya and describes how the data from the Mulyorejo area has been collected and analyzed to be compared with data that has been provided by the Environmental Agency.

The physico-chemical parameters pH (pH-meter), temperature (thermometer), turbidity (nephelometer), total suspended solids (gravimetric), salinity (salinometer), dissolved oxygen (iodimetric), biological oxygen demand (Winkler method), chemical oxygen demand (reflux), total ammonia (spectrophotometric), total phenol (spectrophotometric), phosphate (spectrophotometric) and nitrate (spectrophotometric) have been measured at 4 (four) sampling points in the Mulyorejo area and have been analyzed by the Environmental Engineering lab. The methodology of the lab analysis is described in the 22nd edition of the book Standard Methods for Examination of Water and Wastewater (APHA) by Rice et al. [8].

The biological method consists of the analysis and determination of the vegetation. The vegetation has been assessed by the determination of the Important Value Index (trees: given in Eq. (1); seedlings, saplings and other vegetation: given in Eq. (2), the Shannon Wiener index given in Eq. (3) and the Evenness index given in Eq. (4), respectively.

$$INP = KR + FR + DR \quad (1)$$

$$INP = KR + FR \quad (2)$$

$$H' = \sum [p_i \ln(p_i)] \text{ with } p_i = \left(\frac{n_i}{n}\right) \quad (3)$$

$$E = \frac{H'}{\ln(S)} \tag{4}$$

This analysis has been done along two transect lines consisting of two plots each in the Mulyorejo area. The analysis was done using the following equipment: GPS, measuring tape, rope, preprinted data sheets and pencils.

The two mangrove location points in the Mulyorejo area are found in the mouth of the river and in the middle part of the river. The two fish pond samples were taken on opposite sides of the river close to the river bank. The Biological sample was taken in the bend of the river opposite each other. The Wonorejo area is located in the south part of the coast (Figure 1).

Fig. 1. The sampling locations

Fig. 2. Nutrient values of all areas. The values should be below the line

After each sampling trip, the data was formatted using excel. The data was labelled with a full description of the sample collection procedure including the location, type of

sampler, quantity sampled, number of samples, and types of filtration, apparatus and filters. It was then formatted to have the same format as the provided data for analysis.

4 Results and Discussion

The nutrients are divided in three different parameters; Nitrate, Ammonia and Phosphate (Figure 2). In the Mulyorejo area the nutrient levels are the highest of the three areas and are fluctuating quite severely between the two sample points. The conditions in Wonorejo and Kenjeran are similar but are still higher than the limitation factor.

When looking at the physical parameters, it becomes apparent that turbidity and total suspended solids exceed the limitation factors (Figure 3). Temperature has no limitation factor but has a value that is to be expected in the local climate. The temperature of the samples taken from Mulyorejo is most likely lower because the location and date differ from the other areas.

Fig. 3. Physical parameters. The values should be below the line

The BOD and DO conditions of Wonorejo are in accordance to the limitation factor and have a stable trend (Figure 4). The first sample point of DO in Wonorejo is below the limitation factor which is most likely caused by a divergence of the standard deviation. Both Mulyorejo and Kenjeran exceed the limitation factors of BOD and DO. When looking at BOD there are many fluctuations visible within the locations. Research by Sakinah *et al* [9] shows that in the Wonorejo area these values have great impact on the local system, with values corresponding to the values found in this research. While, Suntoyo and Sakinah [10] have shown that the phenol concentration in northern Wonorejo estuary is higher than other areas based on the numerical modelling simulation.

Salinity does not have any limitation factors but has very significant fluctuations in the different sample points within areas, ranging from almost 0 to 45 ppt (Figure 5). The

Ph should be between 7-8.5 to be in accordance to the limitation factor. As Figure 5 shows, almost all samples lie within this range.

Fig. 4. BOD and DO. The value of BOD and the value of DO should be below the line

Fig. 5. Salinity and pH. The value of pH should be between 7 and 8.5

Table 1 describes the physico-chemical parameters of the fish ponds in the Mulyorejo area. When comparing it to the mangroves in the Mulyorejo area, it becomes apparent that there is little difference between the parameters measured. The nutrients are over the limitation factor, and the same goes for the physical, biological oxygen demand and the dissolved oxygen condition.

Table 1. The physico-chemical values of the fish ponds in the Mulyorejo area

Test Description	Unit	Regulatory Limit*	fish pond 1	fish pond 2
Temperature	°C	Natural	25	24
Turbidity	NTU	5	64	18,4
TSS (Total Suspended Solids)	mg/l	20	96	72
pH	-	7-8.5	7,3	7,05
Salinity	ppt	Natural	20,7	20,9
DO (Dissolved Oxygen)	mg/l	>5	4,6	3,6
BOD ₅ (Biological Oxygen Demand)	mg/l	10	16	12
Free Ammonia (NH ₃ -N)	mg/l	Nihil	0,77	0,73
Phosphate(PO ₄ -P)	mg/l	0,015	0,86	0,44
Nitrate (NO ₃ -N)	mg/l	0,008	0,1	0,07

In the Kenjeran area, the most apparent thing is that area 1 in terms of density (Ka) is considered as good to very dense (density is above 1500 trees/ ha; Regulation of Environmental Minister No. 201/2004) while the density of area 2 is considered as damaged to rare (density is lower than 1000 trees/ ha) (Table 2). The most important species according to the INP in both areas is the *Avicennia marina*.

When looking at the saplings and seedlings in this area, the numbers of these are rising in comparison to the number of trees. In both areas, there is one species found in this category.

When looking at the Wonorejo areas 1 and 2 it can be seen that the density is considered as good to very dense (Table 3). The Wonorejo area 2 however, has a substantially higher density. Wonorejo area 3 has a density that is considered as good to moderate (density is between 1000-1500). In the Wonorejo areas, there are multiple species present but when looking at the INP it can be said that the *Avicennia marina* is the most important and abundant species in these areas as well.

When looking at the saplings and seedlings in this area, the amount of species found is decreasing. The absolute number of seedlings and saplings is however increasing in comparison with the number of trees in the Wonorejo areas 1 and 2. In Wonorejo area 3 there is a decline in the number of seedlings.

Table 2. The governmental data from Kenjeran; this is the coastal part of the Mulyorejo area with Ka in trees/ ha

Kenjeran 1				Kenjeran 2			
Species	ni	Ka	INP	Species	ni	Ka	INP
<i>Trees:</i>				<i>Trees:</i>			
<i>Avicennia marina</i>	55	1833	259,16	<i>Avicennia marina</i>	25	833	300
<i>Avicennia alba</i>	6	200	40,83				
Total	61	2033	300	Total	25	833	300
<i>Saplings:</i>				<i>Saplings:</i>			
<i>Avicennia marina</i>	30	4000	200	<i>Avicennia marina</i>	19	2533	200
Total	30	4000	200	Total	19	2533	200
<i>Seedlings:</i>				<i>Seedlings:</i>			
<i>Avicennia marina</i>	11	9167	200	<i>Avicennia marina</i>	40	33333	200
Total	11	9167	200	Total	40	33333	200

In the Mulyorejo areas the density is considered as good to very dense with only one species present. The number of saplings and seedlings in these areas are also substantially higher than the number of trees found (Table 4).

Table 3. The governmental data from the Wonorejo area; Ka is in trees/ ha

Wonorejo 1				Wonorejo 3			
Species	ni	Ka	INP	Species	ni	Ka	INP
<i>Trees:</i>				<i>Trees:</i>			
Avicennia marina	46	1533	230	Sonneratia alba	3	100	36
Rhizophora stylosa	2	67	21	Avicennia marina	17	567	115
Xylocarpus moluccensis	3	100	26	Rhizophora stylosa	8	267	63
Excoecaria agallocha	2	67	23	Total	40	1333	300
Total	53	1767	300	<i>Saplings:</i>			
<i>Saplings:</i>				Sonneratia alba	2	267	35
Avicennia marina	12	1600	48	Avicennia marina	11	1467	77
Rhizophora stylosa	46	6133	117	Avicennia alba	4	533	44
Xylocarpus moluccensis	4	533	35	Rhizophora stylosa	4	533	44
Total	62	8267	200	Total	21	2800	200
<i>Seedlings:</i>				<i>Seedlings:</i>			
Avicennia marina	4	3333	42	Rhizophora stylosa	1	833	200
Rhizophora stylosa	19	15833	158	Total	1	833	200
Total	23	19167	200				
Wonorejo 2							
Species	ni	Ka	INP				
<i>Trees:</i>							
Avicennia marina	94	3133	300				
Total	94	3133	300				
<i>Saplings:</i>							
Avicennia marina	45	6000	200				
Total	45	6000	200				
<i>Seedlings:</i>							
Avicennia marina	3	2500	110				
Rhizophora stylosa	2	1667	90				
Total	5	4167	200				

Table 4. The data from the researched area; this area is more inland then the other two areas. Ka is in trees/ ha

Mulyorejo 1				Mulyorejo 2			
Species	ni	Ka	INP	Species	ni	Ka	INP
<i>Trees:</i>				<i>Trees:</i>			
Avicennia alba	62	3100	300	Avicennia alba	52	2600	300
Total	62	3100	300	Total	52	2600	300
<i>Saplings:</i>				<i>Saplings:</i>			
Avicennia alba	29	5800	200	Avicennia alba	37	7400	200
Total	29	5800	200	Total	37	7400	200
<i>Seedlings:</i>				<i>Seedlings:</i>			
Avicennia alba	23	28750	200	Avicennia alba	25	31250	200
Total	23	28750	200	Total	25	31250	200

5 Conclusion

When looking at the nutrient concentrations, it is clear that the amount of nutrients is too high in this ecosystem. This stimulates the algae blooms, which influences all aquatic life such as fish and invertebrates, lowering the biomass of the system in the long term. The most probable cause of these high nutrient amounts is domestic waste and urban runoff.

Turbidity and Total Suspended Solids have large fluctuations in their concentrations. They often do not comply with the limitation standards. This could be caused by the sedimentation of the water or the erosion and tidal waves. This causes the water to become more turbid and increases the amount of particles in the system. This makes finding the point source difficult as there are many influences. The Temperature does, in this case, not tell much about the water quality. It is in this area mostly influenced by the local climate and not by pollution.

The BOD and DO are linked to each other, when BOD becomes higher, DO will decrease. BOD is in term greatly influenced by the amount of nutrients present in the system as these nutrients often cause the number of algae to increase. When BOD is high, then this influences the populations of fish and all other aquatic organisms dependent on oxygen. The low concentration of DO might cause the death of some aquatic life.

When talking about the pH it can be said it is neutral, from this we can say that the CO₂ value is also around an average value. The values of Salinity are most likely fluctuating due to the large influences from the sea at high tide and from the river at low tide. The values of Salinity are as expected in this area.

The conditions in the fish ponds do not differ much from the mangroves. This is not in line with the expectations as fish ponds are expected to have a cleansing function.

The conditions of the biological parameters are overall according to the regulations. The Wonorejo area has the highest species diversity while the Mulyorejo area has the highest tree density of all the areas. When looking at the seedlings and saplings it can be concluded that the density in all areas will become higher in the future except for the Wonorejo area 3. The reason that there are only one or two species found in some of the areas is due to the fact that the genus *Avicenniaceae* is a pioneer in mangrove ecosystems. This genus traps the sediment which will allow other species to grow in the future.

Following these results, the next step is to extend the research to find out which nutrient has the biggest influence on this aquatic system to be able to find a solution to limit the influence of these excess nutrients. There is also need to make sure that the trend of the increasing density of the mangrove continues, there should be regular monitoring both in the coastal area and in the inland part of the mangrove. It is also important to find out why in the Wonorejo 3 area the number of seedlings and saplings found is so low to avoid this happening in other areas. And lastly, to prevent problems in the future, the amount of domestic waste coming into the system should be lowered. It is therefore important to find the source of this waste and to find a solution to limit it.

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